<u>Prototyping and Hygiene Demand Assessment of “CoCuCo” Dispenser</u>

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Environmental Engineering

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Abstract

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Prototyping and Hygiene Demand Assessment of “CoCuCo” Dispenser focusses on the development process of mechanical engineering devices. This includes methods tools and prototyping types. 3D printing is looked into as prototyping method and is explained from the very basic generation of needed data formats until some real life experience reports including improvement suggestions. The Hygiene demand assessment is represented with a very basic wipe test analysis. The needed basic compounds for microbiological growth are mentioned and the possible sources for them. The wipe test mentioned earlier is designed to find one of the possible nutrition sources for mycobacteria. To proof the need for protection of the coffee cu covers, samples of covers are taken from the Tampere city area and analyzed with the wipe tests in TAMKs laboratories. The findings of the wipe test lead to a first conclusion of occasional need for protection. This conclusion is a very weak one due to the nature of test method and needs further back up.

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product development, 3D printing, protein testing, prototyping

Contents

1 Introduction

The Coffee Cup Cover dispenser is an invention in the development process. The idea and actual concept is created by, Timo Methler. The original issue is the difficulty to separate "take away coffee covers". There is no standardized way of offering these covers and there for shops place them where and how ever they wish to. This results in possible contamination of the covers and no separation support at all. The thought of creating a mechanical solution was first thought in 2009. It included a rough idea of a separation mechanism for the coffee cup covers. The idea was not followed up. A development team was formed in 2012 and started development to solve the separation issue. The team consisted three members, Thomas Beckert, Torben Langhals and Timo Methler. The development follows a typical evolution path described by experts in field related books. This thesis will describe some of the tools available for development, describes different kind of prototypes, explains the concept of 3D printing including an experience overview of made mistakes and talks about the importance of proteins for bacterial growth including a testing mechanic. During the development process the team decreased its members to only Timo Methler after the first system iteration.

2 Theory

2.1 Product development process

Product development has many facets in many different fields, engineering, marketing, business, design to name a few. Every field has their own structure how the development should be organized. This thesis will be focused on the engineering part of product development and some actual prototyping methods. The process of development should be well organized and documented to ensure creditability and efficiency.

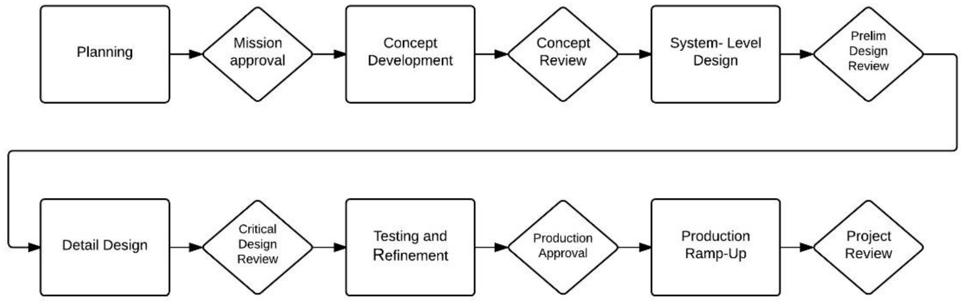


Figure 1 Generic Product Development Process (Ulrich and Eppinger 2012)

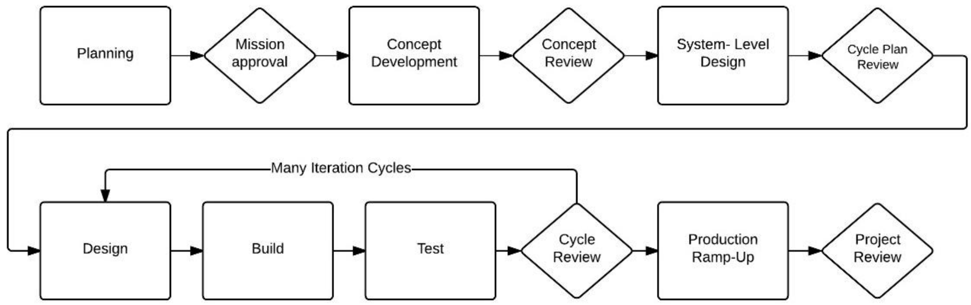


Figure 2 Spiral Product Development Process (Ulrich and Eppinger 2012)

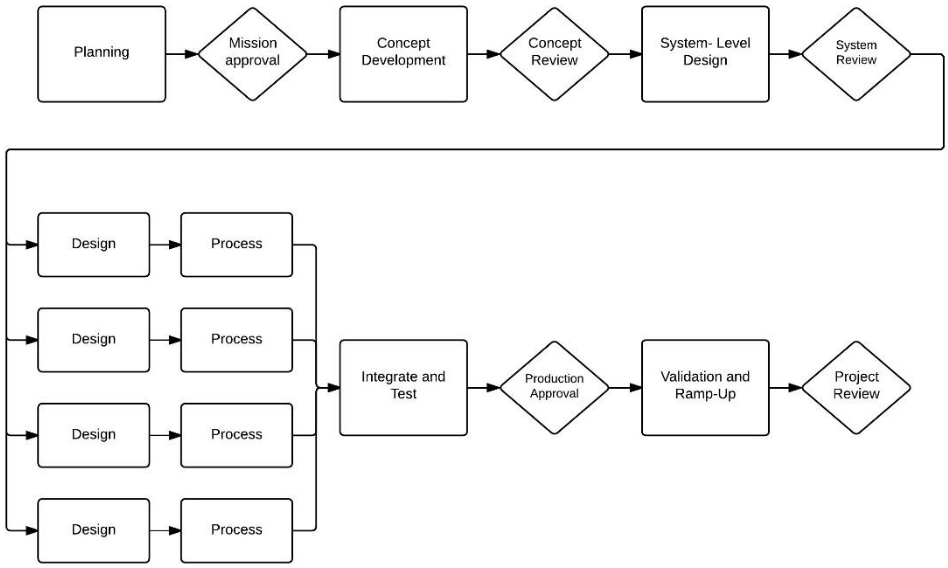


Figure 3 Complex System Development Process (Ulrich and Eppinger 2012)

Figure 1 to Figure 3 show different concepts for product design. Generic process development is a mainly used approach to market-pull, technology push, customized and other basic developments. The spiral development approach is used for developments, which can create quick prototypes, such as IT solutions, engineering with digital approaches and other quick build developments. Complex system development process is needed for complex projects with many subsystems and various components. The gateways between the phases are designed to ensure progress and verify the achievement of set goals. Most people would think the generic product development is the optimal concept, but most literature and experienced developers emphasize the importance of iteration and multiple approaches to get the optimal result. In fact all gateways are also designed to identify the need to go back to any previous phase. All of the represented steps have structures build into themselves and recommended Methods. These deeper Methods vary from more detailed flow charts to list of possible important properties, which should be checked. (Ulrich and Eppinger 2012)

A list of properties which should be checked for every part on every goal is:

1. Functionality
2. Strength/ stress
3. Distortion/ deflection/ stiffness
4. Wear
5. Corrosion
6. Safety
7. Reliability
8. Manufacturability
9. Utility
10. Cost
11. Friction
12. Weight
13. Life
14. Noise
15. Styling
16. Shape
17. Size
18. Control
19. Thermal properties
20. Surface
21. Lubrication
22. Marketability
23. Maintenance
24. Volume
25. Liability
26. Remanufacturing/ resource recovery

(Budynas and Nisbett 2011)

Applicability of some of the criteria's have to be considered if applicable at certain phase or certain development type.

The Planning of a new development includes many steps. The first step is to pinpoint a need for improvement or identification of opportunity. The source of this can be of any kind, costumer suggestion, marketing suggestion, new generation needed to stay competitive, private idea and many other sources. For validation of these opportunities or needs for improvement a customers need research can be conducted. Customer need research includes, data collection, analyzing and refining of data. The collection itself can be done via interviews with single person, with groups of 8 to 12 customers or observing product in use, by developer's them-self or customers. The estimated knowledge gain is visualized in Figure 4. (Ulrich and Eppinger 2012)

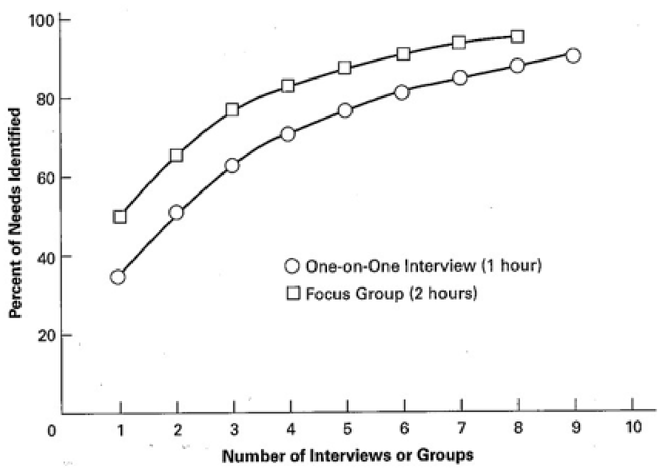


Figure 4 Customers' needs knowledge acquired (Ulrich and Eppinger 2012)

The acquired statements and experiences need to be interpreted into actual needs. Both the formulated need and the original statement or experience should be documented. The development team decides a strategy goal and uses it to prioritize the needs in an optimal way. Common strategy goals are, Technology leadership, Cost leadership, Customer focus and Imitative. The names are self-explaining and set the direction of which the development team should orient them during all times. The decided strategy is then used to define resources and time planning, the different strategies need different resources or time. For example a customer oriented development should keep celebrations like Christmas in mind for the time plan, as well as technology leadership developments need different kind of developers than imitative developments. Along with the project timing a mission statement is formulated, it includes all important information and advices. (Ulrich and Eppinger 2012)

The concept development sets the basic principle for the solution. The desired solution should be broken down in as many simple solutions as possible. For example a flashlight could be broken down into, energy storage, light emission and energy transfer to emission source. Every sub solution can then be addressed in different ways. The light emission for example could be solved by, glow source, LED, OLED, laser or other solutions. All of the sub solutions should be documented and discussed. As decision help often a concept combination table (Figure 5) is used, every possible solution for the subsystems is written on it and a line connection marks the combined chosen solutions. (Ulrich and Eppinger 2012)

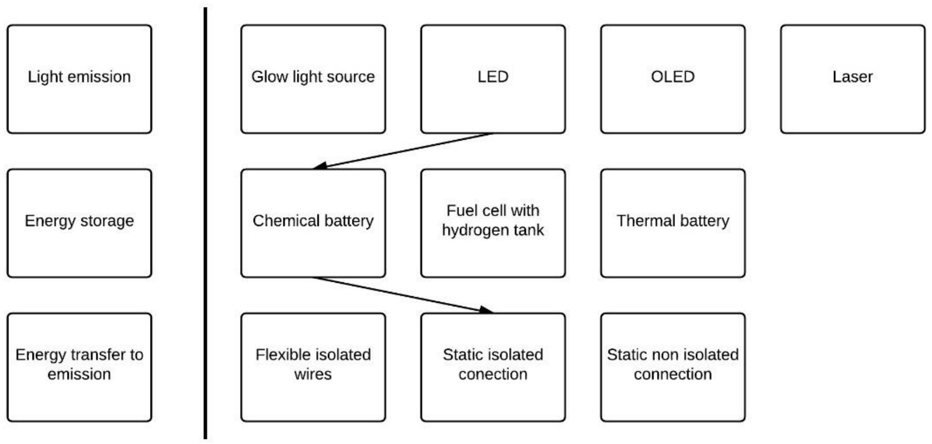


Figure 5 Concept combination example table

During the System level design the product architecture, connections between the subsystems and subsystems them-self get defined. These sub-systems are called chunks. The basic designs of each chunk is done, without detailed planning such as materials and tolerances. The chunks can be prototyped and tested if they are working as intended. The interaction between the rough chunks needs to be tested during system design as well as preliminary process flow charts for the final assembly and production methods get laid out. The detail design phase is then used to specify every single part. Every part needs to be addressed with tolerances, materials, production processes and other necessary details. During detail design sub suppliers for the parts need to be found or preparations for production in own facilities needs to be done. The marketing and financial departments need to get heavily involved to plan the actual introduction into the market. The final phase production and ramp-up is the execution of all plans. Marketing runs, production starts and selling of the finished product is initiated. (Ulrich and Eppinger 2012)

2.2 Prototyping

Prototyping is a big part of product development. Prototypes are needed for visualization, experimentation, analyses, proof of concepts, haptic testing. To cover all these applications for Prototypes there are various kinds of them. Every development process creates some kind of prototype.

2.2.1 Categories

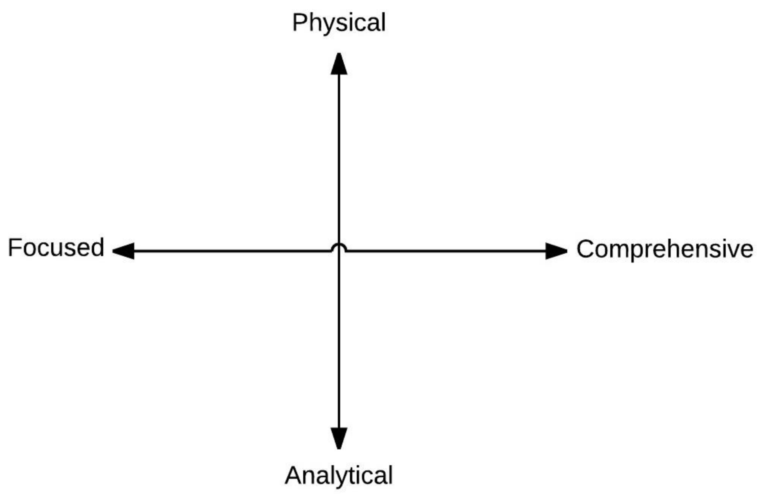


Figure 6 Prototype classification matrix (Ulrich and Eppinger 2012)

Prototypes are essential for development processes. The different kind of prototypes can be classified in the matrix shown in Figure 6. Physical prototypes are used for haptic testing, visualization, and proof of concept as well as functionality. Analytical prototypes are 3D model versions or mathematical representations, these are used for visualization, structural calculations, geometric interference detection and proof of concept simulations. Comprehensive prototypes are system oriented, the test some applications in concert. Focused prototypes are made for one purpose only, to prove a single process or to visualize/ give haptic example for a single thing.
(Ulrich and Eppinger 2012)

2.2.2 Plastic 3D printing

Plastic 3D printing is the main prototyping method during the product development described in this thesis and therefor will be addressed in function and quality. 3D printing is in general terms a practical triple integration.

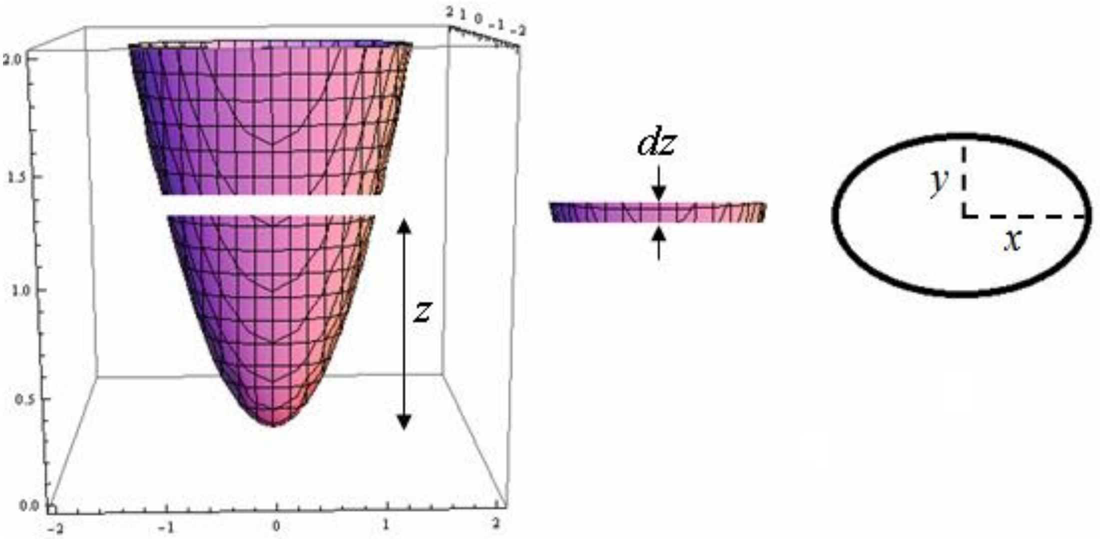


Figure 7 Mathematical triple integration (Unknown 2010)

In Mathematics the body is created by infinite “dz’s”, which should be infinitely small. Figure 7is a visual explanation of the concept. 3D printing takes these fictional “dz” values to a finite level. “dz” is in 3D printing the layer height and can be adjusted from print to print, usual heights are 0,01mm to 0,2mm, depending on printer and desired quality. The “integration” of all layer then form the to print part.

In practice that means that a regular 3D computer model is taken by special “slicing software” and converted into faces with a height between 0,01mm and 0,2mm. These faces in turn will be filled with lines, which will then be followed by the print head of the printer.

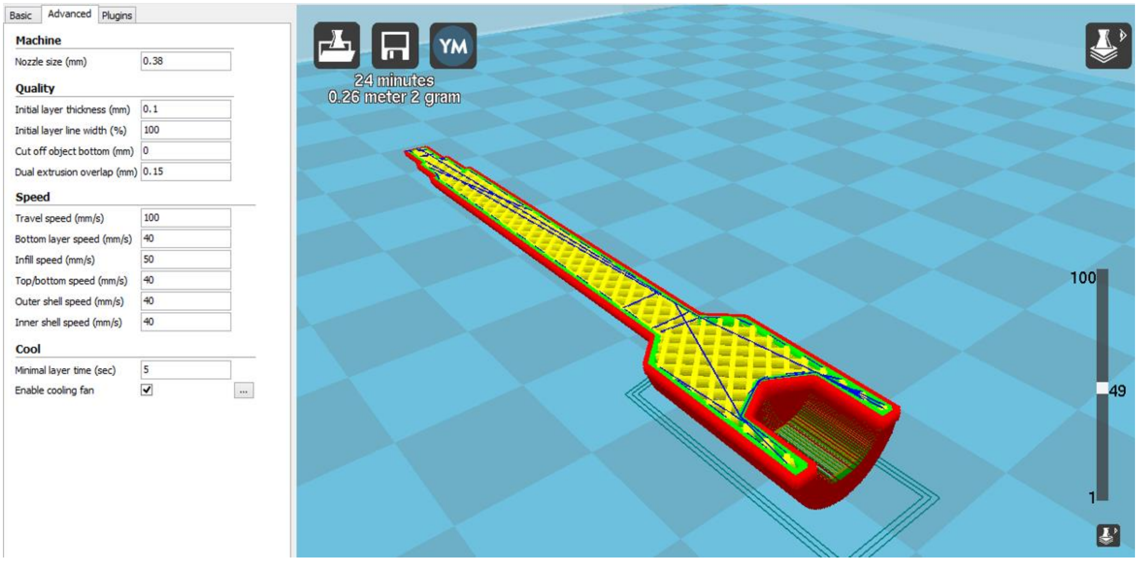


Figure 8 Slicing software "Cura 15.0"

Figure 8 shows the slicing of a pat print, the used program is “Cura 15.0” and is a typical example for private user slicing software. On the right hand side is shown that the part is sliced into 100 layers. Each layer can be visualized by the software, on time of the screen-shot layer 49 is shown. The slicing software defines the toolpaths and all surrounding commands like, speed, heat, material flow, printer specific setups, and more important commands. The parameter is visible on the left hand side of Figure 8. The model is shown with yellow, green and red lines. These lines are the visualization of the travel path the extruder will take. The color of the lines indicate what kind of data set is used for that particular path.

Yellow: “filling” high speed, high material flow and therefor more heat required.
Green: “secondary outer shell” slow speed and moderate material flow.
Red: “outer shell” slow speeds and controlled material flow.
Blue: travel path without material output.

The created commands and pathing instructions are then saved in a format called .g-code. The g-code is printer specific and contains all commands from setup to print process to shut down. The transfer of this g-code to the printer varies from printer to printer, some need the code on a SD-Card and act self-supported, there are also printers which need a USB connection to a computer and supporting software running on the computer to read and execute the g-code.

Modern Plastic 3D printers are able to print most thermoplastics and in some cases with additional materials in them. The materials are usually in wire form and on scowls to ensure continues availability of material. Inside the printer itself are an extruder and its material feed, together they form the “print head”. Both are designed for a specific thickness of material. Figure 9 is a concept drawing for a regular 3D printer, the method is called fused deposition modeling. The Material feed is regulated by the programming to feed the set amount of material. The amount of material can be adjusted within the Slicing Software. The extruder melts the incoming material and deposits it in lines onto the part in print. Once in place the material cools down and solidifies in the process. Due to the hot environment around the extruder and the liquid deposited material the new lines fuse with the already printed layers.

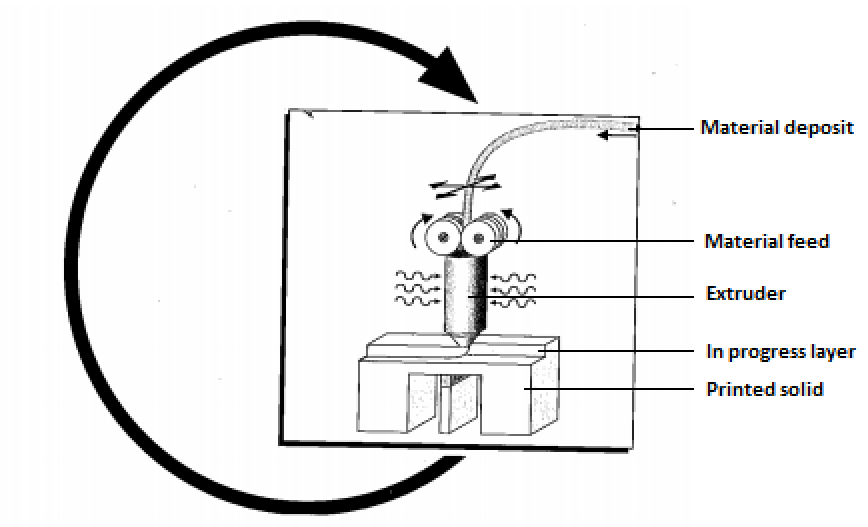


Figure 9 Fused deposition modeling (FDM) process, principle (Gebhardt 2003)

The fusion of the lines with their surrounding is necessary for the lines to support each other. Only this support between all lines enables the creation of durable parts.

2.3 Hygiene

95% of all cell dry weight of microorganism is made of the “macroelements” or “macro nutrients”. These 11 macroelments are: carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium and iron. The first six (C, O, H, N, S and P) are components of carbohydrates, lipids, proteins and nucleic acids. Therefor at least one of these is necessary for microbiological growth. (Willey, Sherwood and Woolverton 2009) The macroelment donators have different methods to detect them. The company Orion offers a wipe test to test for proteins. This test is designed to be performed without specialized equipment. Most testing methods for proteins and the other macroelment donators require complex equipment. The simplicity of Orions wipe test, called Clean Card, promotes them to a popular test method. The provided result is a rough estimation if proteins are present. Orion claims to detect proteins starting from 50µg per 100cm². (Orion 2013) Each test area is tested by a onetime use Clean Card (Figure 11). If more proteins than 50µg are present the indication area of the clean card changes color from a light yellow to green or blue. The more change the more proteins are present. For comparison Orion provides a scale shown in Figure 10. This simple wipe test can be used to verify the need for further more accurate testing.

Figure 10 Clean Card scale (Orion 2013)

Figure 11 Example Clean Card (consulting n.d.)

3 Actual coffee cup cover dispenser development

Figure 12 is a flow chart of the development process the coffee cup cover dispenser team executed. The spiral development path was taken due to the fast prototyping possibilities with 3D design software and access to a 3D printers. The following chapters show the content of the most important parts.

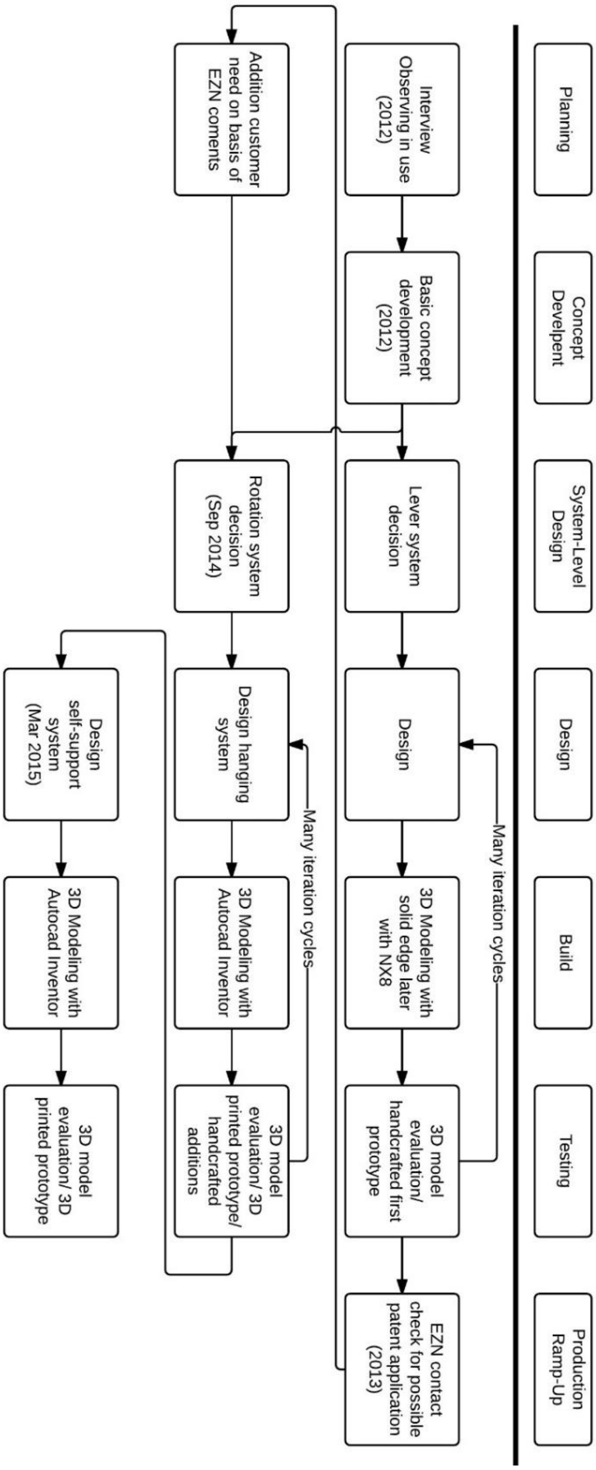


Figure 12 Actual development flow chart

4 Planning

Figure 13 shows a typical display of coffee cup covers. These covers are mostly offered in cafes, gas stations, kiosks, cafeterias and many other places.

Figure 13 Coffee cup cover Stack TAMK 21.04.2015

To identify customer needs ten interviews were conducted. The interviewed customers where shop employees of the relevant industries and actual customers of these. The biggest concern all interviewed employees shared were space. A difficult part is that the counter or service space is very limited. During the interviews and the examination of the environment became obvious that surfaces differ very much, some counters where made from wood some steel some even had stone surfaces. It became also apparent that system can’t require permanent attachment to the counters for cleaning and readjusting purposes. The interviewed employees also pointed out the non-availability of electricity in most service stations. Another issue the shop employees brought up was that if we contain the Covers, they need to know how many cover are left inside of the dispenser and how to refill it. Close to all interviewed customers emphasized the need for a solution which not only separated the cover, but also attaches them to the cup in a reliable way. In case of exchanged contact information with the customers, all customers contacted the team to complain that since the interview they started to be disgusted by possible contamination, which they hadn’t been before.

The contact person at the German patent support institution, brought up the possible hygiene importance of the concept and the possibility for law requirements. He pointed out that there is no protection for random contamination nor intended contamination, by people which are looking to get a clean coffee cup cover from the middle of the stack. (Speckbacher 2012)

The observation of product in use while the team handled the covers, showed that simple gravity would not be enough force to separate the covers at all times, additional force would be needed. Also during the product handling the issues of small force introduction area and the bendability of the covers became apparent. The discussion between the team also came up with many to consider parameters.

Table 1 Customer need interpretation

Statement by costumer	**Interpreted need**
I would like to have help with the separation	handling support
I would like to have a machine to attach the cover onto the cup	cover attachment to cup
I carry disinfection cloth with me to wipe coffee cup covers	Hygiene protection
Statement by employee	**Interpreted need**
We don't have much space on the counter or service station	solution size needs to be small
We don't have electricity at the service station	manual solution
I need to know how many covers are on display	fill indication
I need to be fast with the refill	easy access refill ability
Statement by development team	**Interpreted need**
Bendability of the cover needs to be respected	large contact area for handling
Covers sometimes stick together	separation force
Small kiosk, no big capital	manufacturing price low

5 Concept Development

The concept combination table in Figure 14 Concept combination table Figure 14 offers many different combinations of solution approaches.

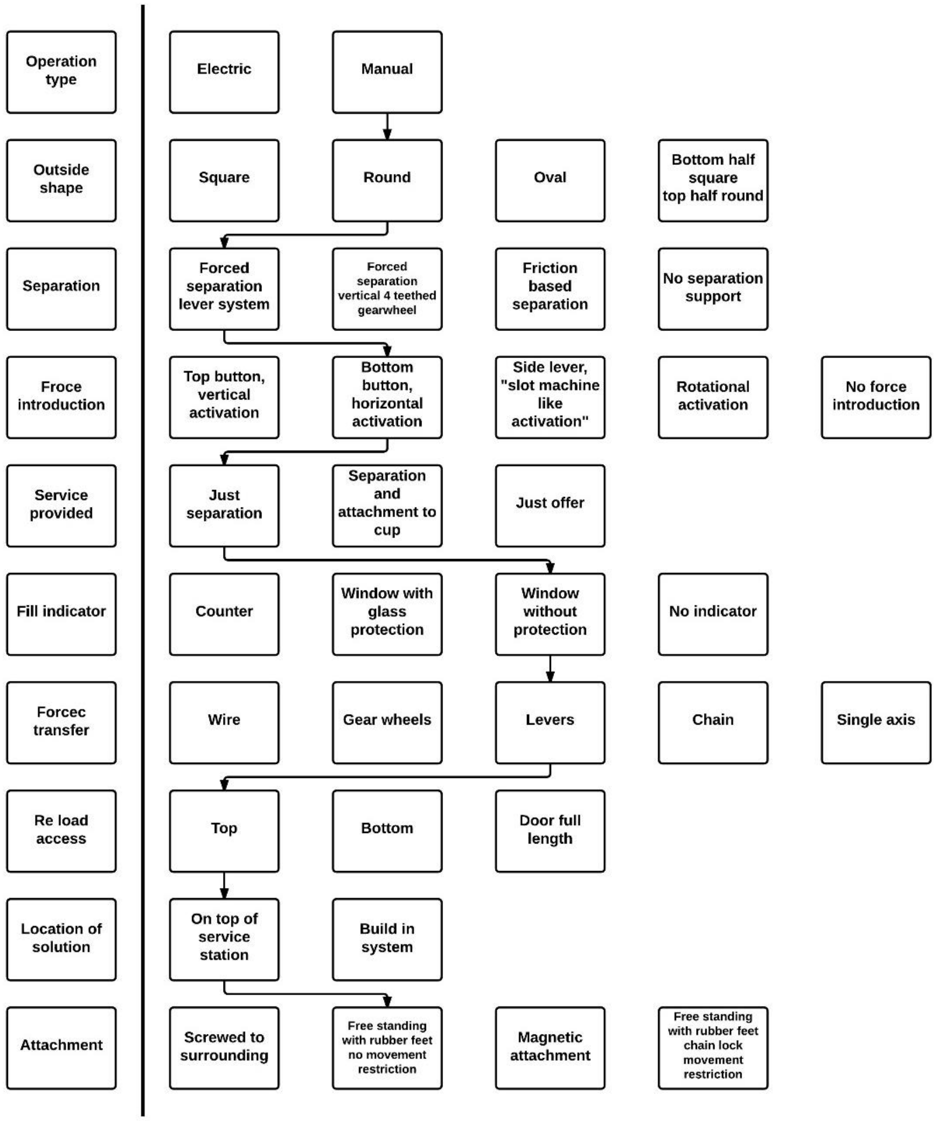


Figure 14 Concept combination table (Ulrich and Eppinger 2012)

All mentioned variations in Figure 14 were discussed in the original three man team. Operation type was selected due to the notion of employees that there is not always electricity available and a manual approach widens the possible use locations. To ensure a separation of the covers at all times, a forced separation system was decided. The four teeth gearwheel approach was easier to realize, but was not selected due to the fear that the small area of force introduction would bend the covers out of shape. The service selection was settled on separation only, even though many customers had requested a solution which attaches the covers. The attachment system had multiple down sides during discussion, the main concerns where the centering of the cup under the cover and the amount of required movement of the customer to execute the attachment. The fill indicator was selected to be a simple window to reduce the amount of moving parts and systems that could fail. Force transfer was the biggest discussion within the team the lever system got selected because of recently gained expertise with lever of a team member. A build in solution into counters was strongly favored by the team due to esthetic reasons, but the difficulties to change existing counter made the “on top of counter” solution the selected concept part. The way how it is supposed to be on the counter is free standing. The team decided to not screw it to surfaces to not damage existing counters and make the dispenser mobile. For anti-theft reasons a small chain attachment could be included in the final version.

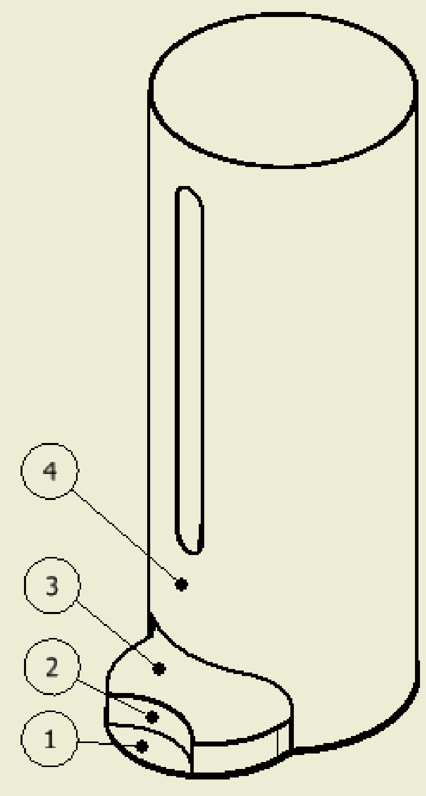


Figure 16 Concept drawing

Part No.	Name
1	Ground plate
2	Button
3	Serving plate
4	Housing

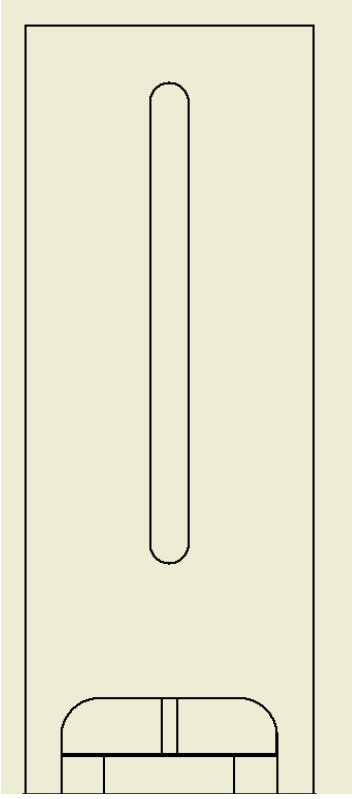


Figure 15 Front view concept drawing

Figure 16 shows the outside view of the general concept, which got selected by the concept combination table. The serving area (Part 3) visible in Figure 16 presents the separated covers, the circular shape on the very tip is to support the grab ability of the covers. Between the serving plate and the ground plate are the mechanics located. The mechanics vary from concept to concept and will be shown in chapters 6 and 6.2. Above the separation level marked in Figure 17 are the covers stored. The separated cover drops down and lies ready to be pick up on the very tip.

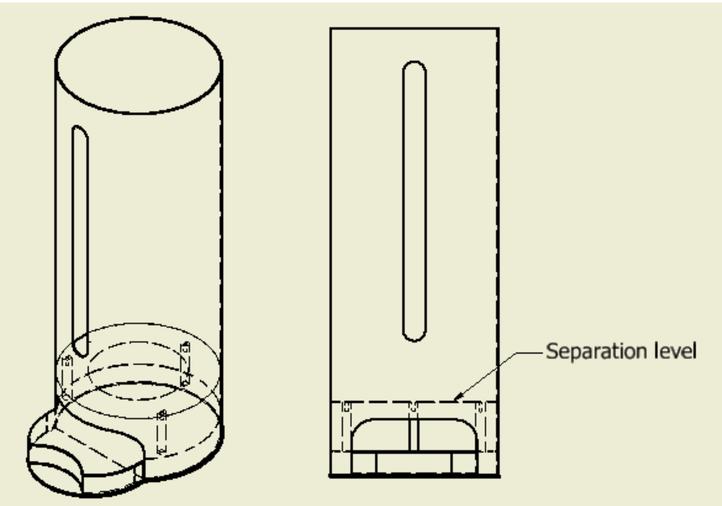


Figure 17 Concept drawing, marked separation level

6 System development

The whole architecture of the basic concept is divided into two chunks, the separation and the force transfer. The force transfer chunk is located under the serving plate and the separation chunk on the separation level. The following section will explain the chunk concepts briefly.

6.1 System 1 the "Lever system"

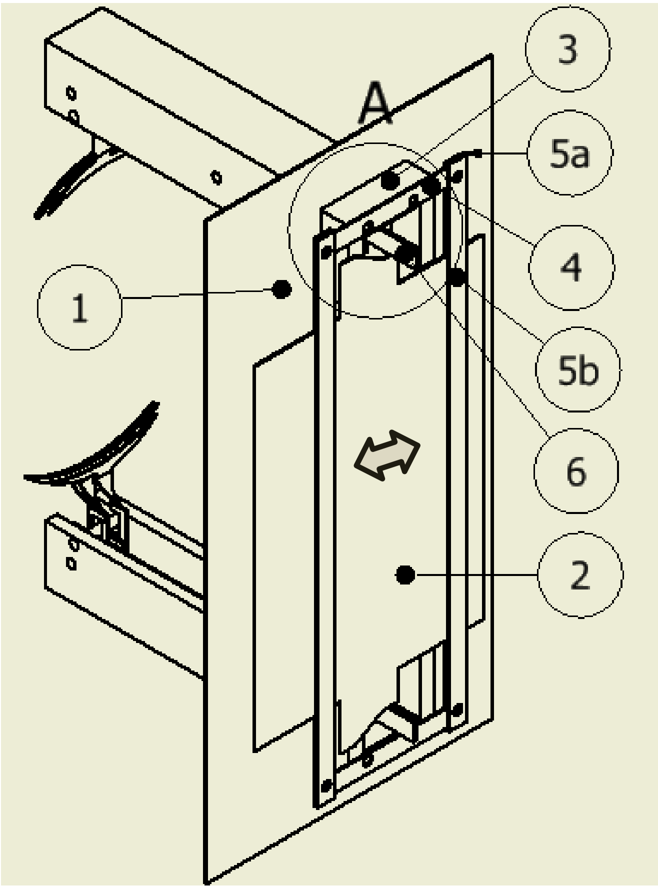


Figure 18 Lever system basement drawing

Part No.	Name
1	Ground plate
2	Button extension
3	Distance U profile
4	Diagonal attachment
5 a/b	Guide/ attachment
6	Vertical lever

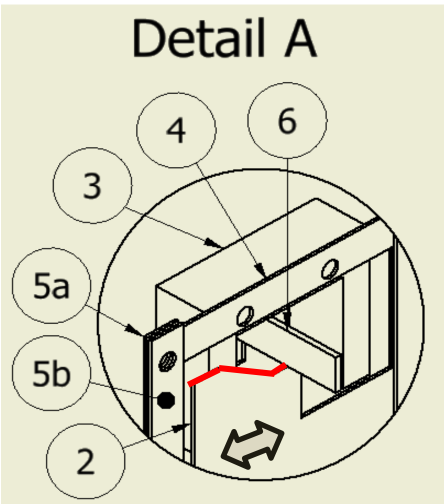


Figure 19 Detail A to lever system basement

The force transfer chunk of the lever system is activated by the button (part2 on Figure 16). This button is fused with part 2 on Figure 18 as soon as the customer presses the button with its extension the system is activated. The movement of part 2 forces part 6, the vertical lever, to the outside of the system, due to its outer shape, visible in Figure 18 and marked (red) in Figure 19.

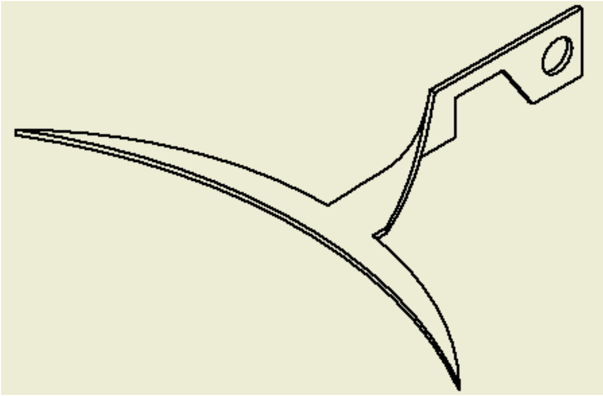


Figure 21 Separation lever (part 9)

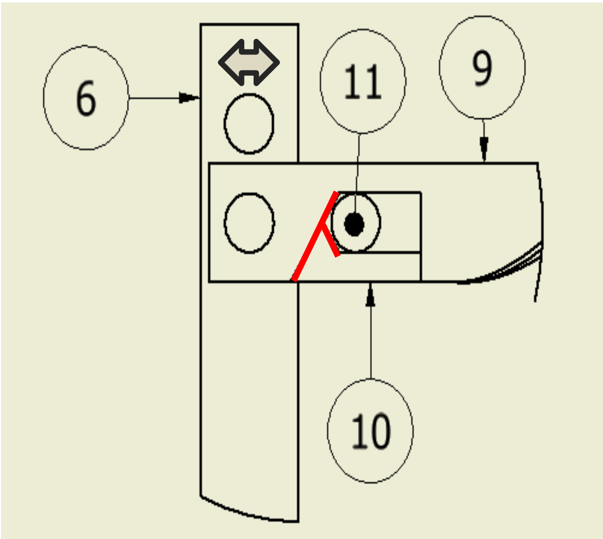


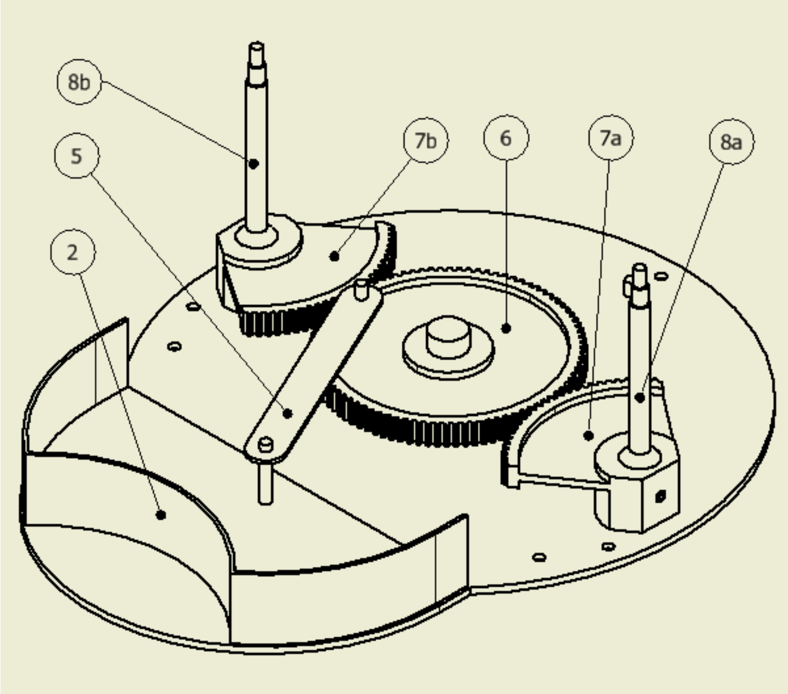
Figure 20 Separation mechanism in lever system

Part No.	Name
6	Vertical lever
9	Separation lever up
10	Separation lever down
11	Stationary separation rod

The separation chunk of the lever system uses levers in a half-moon shape to handle the covers. The half-moon shape was selected to maximize the contact area between cover and lever. An example is shown in Figure 21. As shown in Figure 20 the separation levers are connected to the vertical lever. This lever is the one which gets moved by the button push and represents the connection between the two chunks. As soon as part 6 (vertical lever) moves, the two attached separation levers, displayed in Figure 21, move onto the stationary separation rod, part 11. The shape of the two separation levers, marked in red in Figure 20, force the two levers to separate from each other. This movement separates the cover from the bottom of the stack, inside the coffee cup cover dispenser.

6.2 System 2 the “Rotational system hanging”

The force transfer chunk of system 1 got changed due to issues with the positioning of the button, noise of scratching metal and non-constant force requirement of the system.



Part No.	Name
2	Button
5	Rod
6	Flywheel /centre gearwheel
7	Side gearwheel
8	vertical axil

Figure 22 Rotational system basement drawing

The second systems force transfer chunk is drawn on Figure 22. Part 2, the button, which is already in Figure 16 Concept drawing, needs a pushing distance of 10mm to run the system through a full cycle of action. The linear force is then transferred by the rod (Part 5) onto the fly- gear wheel combination (Part 6). The center gearwheel transfers the force onto the two side wheels (Parts 7a/b). The gear ratio is shown in (1).

$$(1)\ R = \frac{r_4}{r_{3a/b}}\ with\ r_4 = r_{3a/b} => R = \frac{r}{r_4} = 1 \text{ (Wittel, et al. 2012)}$$

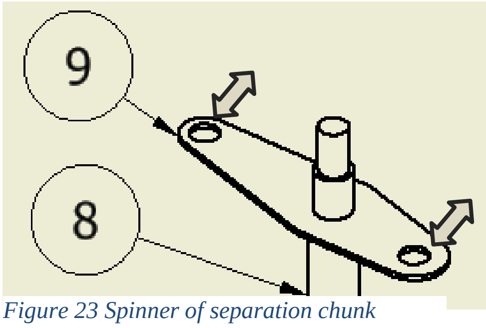
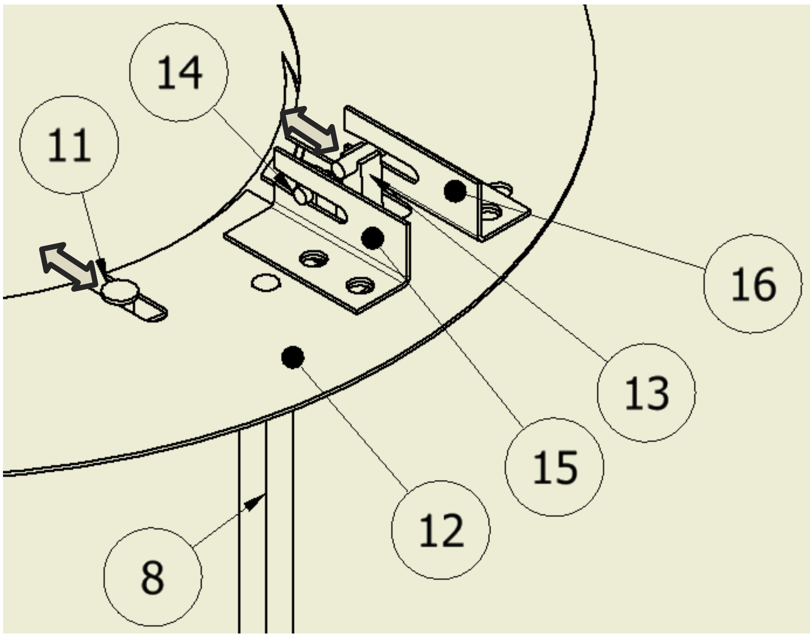


Figure 23 Spinner of separation chunk

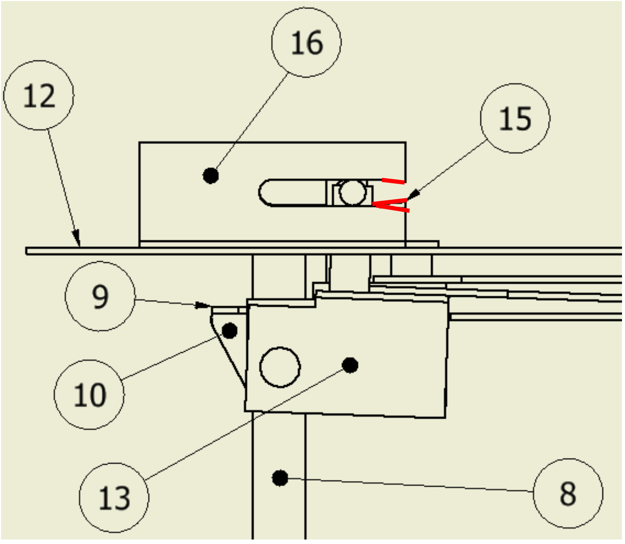
The rotational force is the interaction between the two chunks. The separation chunk then uses a spinner to widen the radius to get a semi linear movement. The movement executed is 3mm linear. The two holes are there to attach the levers to them. The longer side is attached to part 11 and the shorter side to part 10 and extension 13/14.



Part No.	Name
8	Vertical axil
11	Resting lever
12	Orientation
13	Separation extension down
14	Separation extension level
15	Guide extension level
15	Guide extension down

Figure 24 Separation mechanism with orientation

Figure 24 now shows the separation chunk from a top view. Parts 11, 13 and 14 hang in their orientations, which give the system its name, the parts are the levers or are fused to the levers. The levers are still half-moon shapes as in the lever system and handle the covers in the same way.



Part No.	Name
8	Vertical axil
9	Spinner
10	Angle
11	Resting lever
12	Orientation
13	Sep. ex. down
13b	Sep. lev. down
14b	Sep. lev. level
15	Guide ex level
16	Guide ex down

Figure 25 Separation mechanism side view

The side view shows in Figure 25 shows the guidance of the two separation levers (parts 13 and 14). The guidance’s 15 and 16 guide their respective lever, either up or down, as soon as the linear movement of the lever is executed. The important edge section is marked red in Figure 25.

6.3 System 2.5 the "Rotational system self-support"

System 2.5 keeps the same force transfer chunk as system 2.0 and there for the interaction between the chunks remains a rotational force, delivered with the vertical axil. The changes to the system where done after experiencing issues during prototyping with the system 2.0 separation chunk. The development team decided with more controlled movement and not relying on gravity for guidance.

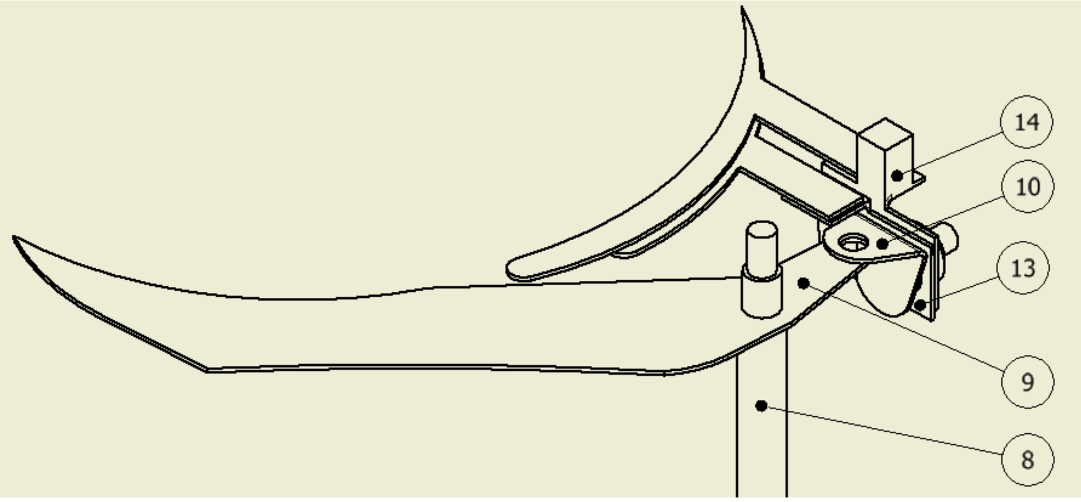


Figure 26 Separation mechanism close up drawing

Part No.	Name
8	Vertical axil
9	Spinner/ resting lever
10	Angle 2.0
12	Orientation
13	Sep. ex. down2.0
14	Sep. ex. level 2.0

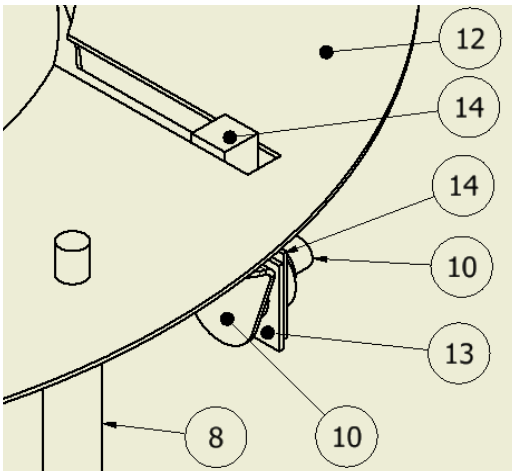
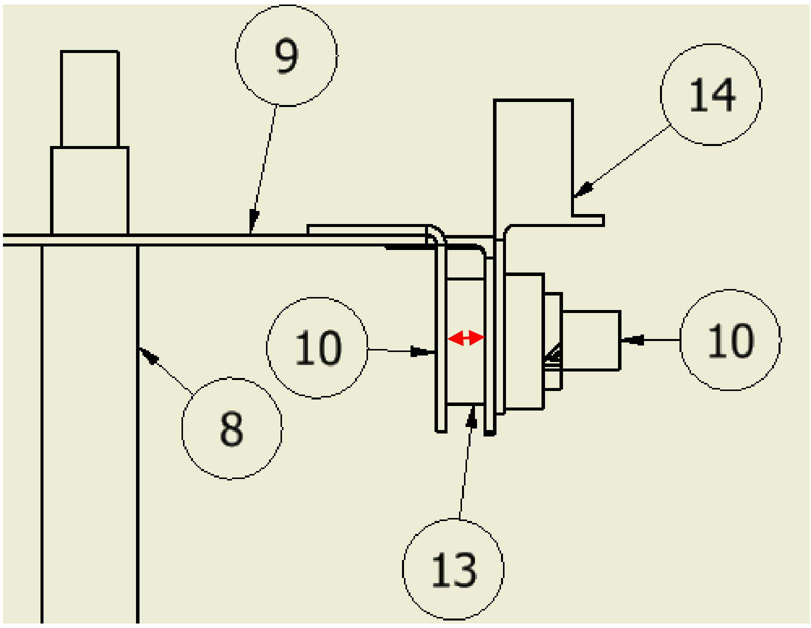


Figure 27 Self-support orientation drawing top view

A major change to the separation chunk is the removal of one of the handling levers and integrating it into the spinner. This removes a pivot and one hanging part. The two other hanging levers were adjusted as well. Figure 27 is the same top view as Figure 24 there are no longer hanging parts in the system. Part 14 is only restricted in its movement to the sides. Part 13 doesn't show up on top of the orientation any more.



Part No.	Name
8	Vertical axil
9	Spinner
10	Angle 2,0
12	Orientation
13	Sep. ex. down 2.0
14	Sep. ex. level 2.0

Figure 28 Separation mechanism self-support close up drawing

From the back view (Figure 28) the arrangement of the parts is visible. Part 10 and 13 are constantly pushed apart by a spring between them. Part 14 is the element which keeps them together, because part 14 is restricted by the orientation visible on Figure 27.

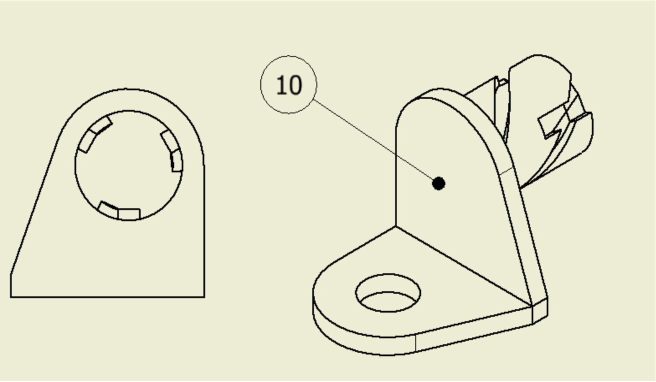


Figure 29 Angle 2.0

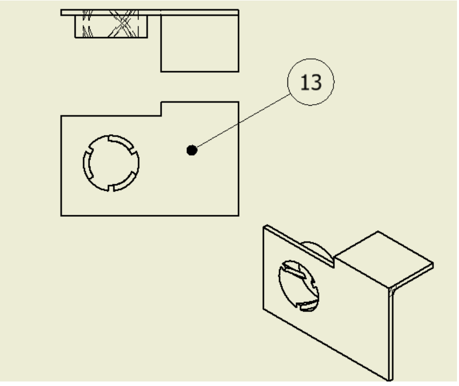


Figure 30 Separation extension down

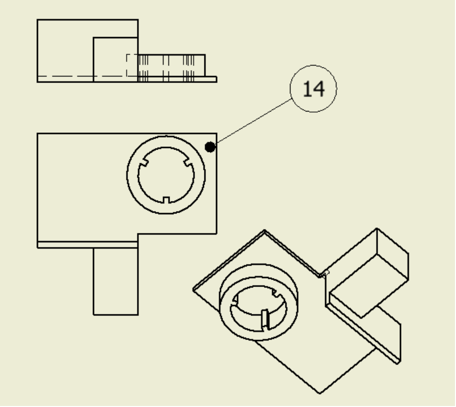


Figure 31 Separation extension level

Parts 13 (Figure 30) and 14 (Figure 31) are wrapped around the angle (part 10). The angle has two sets of grooves in it. One set of three groves with pitch and one set of three groves without pitch. Part 13 runs in the groves with pitch and therefor rotates around the attached axil on the angle. Part 14 runs in the groves without pitch and is there for not able to rotate. The rotational movement of the spinner takes the angle and the separations extensions, on their linear path to the center, farther away from part 14's guidance in the orientation. That creates space between the angle and part 13. The two extensions run along their "grooved" paths and separate as a result of that.

7 Prototyping

Analytical prototypes are very easy to produce with modern 3D design software. These analytical prototypes are used for most illustration during the CoCuCo dispenser development. The team decided to start creating physical prototypes, because the difficulty of imagining the real life sizes. Due to the ability in 3D design programs to zoom in the designer tempts to loose relations to actual producible parts. The decision to use 3D printing as physical prototyping method was done because of access and the simplicity to transfer the existing analytical prototypes into physical ones.

7.1 Plastic 3D printing

Plastic 3D printing is a new technique, compared to other production methods. Due to this fact there is a rather low or none literature and teaching materials available. The Development team had some guidance by students, but made most of their experiences via trial and error. Plastic 3D printing has many parameters which have to be set manually and influence the outcome of the print. The following pictures will illustrate the experiences and will suggest alternative courses of action.

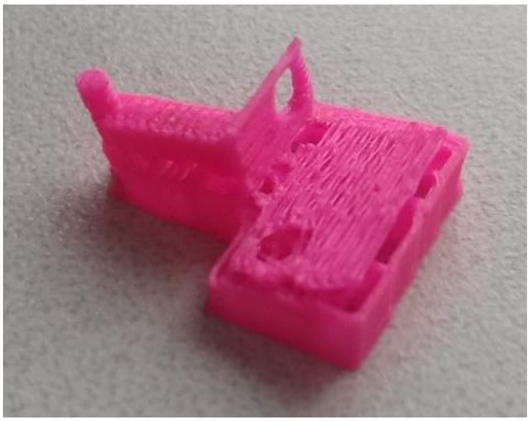


Figure 32 Miss designed part 13 of the hanging system

Displayed in Figure 32 is a printed part, which shows the most important thing to note about 3D printing, the design itself. The way how the structural integrity of the part works is that the lines, which will finally form the whole structure, support each other. The file used to create the toolpath for printing, was the design made for a part created of sheet metal. Therefor the thickness was 0.5mm. This small thickness doesn't provide enough layers to support each other. The pictured attempt in Figure 32 was an attempt to print the part on a 30°. As visible in Figure 32 there are not enough lines to support each other. There are even free spaces between them. This shows rather nicely that designs might have to be changed to be printable. More advanced printers with smaller minimal layer thicknesses, might be able to print such a thin part, but the structural strength remains questionable.

Figure 33 Part 2 half of the suboptimal printed button

Figure 33 shows another suboptimal print due to not optimized design for printing. The wall thickness was designed to be 2mm (CAD thinking). The extruder diameter is 0.38mm and shell thickness 0.74mm (standard value), therefor the slicing software created four paths (two shell sections) 0.38*4=1.52 + filling lines 0.48mm. The filling lines would have had the same pattern as the bottom lines, and where due to the short distance not printed. The thickness of the wall could be adjusted in the CAD model to fit the 1.52mm of shell material. This would prevent the empty 0.48mm and would increase the structural integrity significantly. Another solution would be to make the wall +3mm to get a nicely printable structure.

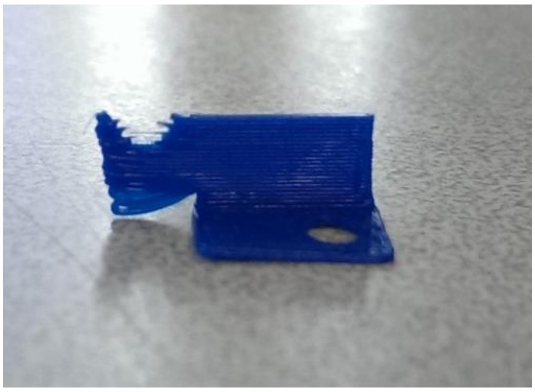


Figure 34 Part 13 thin and un-angled attempt

Figure 34 shows again a very thin part (0.5mm), but this one shows another issue rather nicely. The issue of printing on thin air. On the left hand side "hang" the lowest of the printed lines. This is a problem if is that if there are too big gaps between supports the material starts to "hang" or fall. A very reasonable distance is 0.5 * extruder diameter, this can vary if material or temperatures get adjusted. More advanced printers use support materials to prevent "hanging". These support materials can be dissolvable or just removable by regular tools. A solution to this is to print in two turns and glue the parts together afterwards.

Figure 35 Part 16 of hanging system vertical part

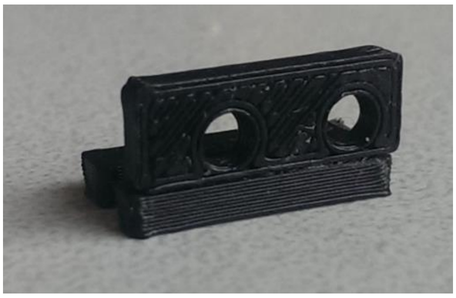


Figure 36 Part 16 of hanging system horizontal part

This two turn print needs more adjustment inside of the slicing software but can easily be done. The glue needed to unite the parts needs to be considered and can be optimised. In this case regular "super glue" from Loctite was used.

Figure 37 deformed part results of being impatience

Figure 37 shows a part which got deformed during the separation from the printing plate. The ground plate of the printer is heated to reduce shrinking of the plastic. The shrinking would separate it from the glass ground plate, because the connection is adhesion only and can be broken by trans lateral movement between part and ground plate. After the print is finished the plate starts to cool down. If the operator tries to separate the Part from the ground plate in a warm state, the plastic will deform.

Figure 38 Part of the resting lever of hanging system

The part of the resting lever shows two things to consider. “Small” vertical structures tend to overheat. If the printer tries to extrude the next layer onto 3-4 un-cooled previous layers, flex with the moving nozzle and create the unregularly shape visible in Figure 38. This issue can be addressed by adjusting temperature, print speed or if possible breaks between the layers.

Figure 39 Vertical attachment not shown in the concept drawings

Figure 39 is the result of adjusted parameters via try and error.

8 Hygiene assessment

For hygiene assessment samples are taken from five locations near the main traffic routs. All sample locations where asked for a new cover from a stored package, a cover from the top of the stack, a cover from the middle of the stack and one from the bottom of the stack. The acquired samples are stored and labeled in sampling bags with zip closing system.

Figure 40 Sample location 1, near the main bus stop

Sample location ones offering system, for the covers, is pictured in Figure 40. The shop is located 10m from the main bus stop in the city center of Tampere. The covers are offered directly next to the cashier and are arranged mouth piece down. The Separation of the cover where very hard even with two hands, the separation is done by the customer. This location was able to provide all four samples and the new cover was taken from a freshly opened package. The new package was stored in a back room.

Figure 41 Sample location 2, near the main bus stop

Figure 42 Sample location 2, close up

Sample location twos offering system is shown in Figure 41 and a close up of the main area in Figure 42. The shop is located 20m from the main bus stop in the city center of Tampere. Sample location two has no system at all, the spot for taking the coffee and covers is far away from the counter and is handled by the customers only. As marked in Figure 41 there are multiple stacks of covers available. The samples were taken from the multi-color stack in the back of Figure 42. There was no new package available and there for only three samples from the stack where taken. Separation of these cover were very easy.

Figure 43 Sample location 3, inside a central shopping center

Sample location three is located inside a central shopping center in Tampere. The offering system is shown in Figure 43, as visible they are on the counter next to the cashier. The customers themselves handle the covers. There was no stockpile package available and there for only three stack sample where taken. Separation of these cover was okay.

Figure 44 Sample location 4, inside the main station

Sample location four is inside the main station of Tampere. Separation of these covers were okay and a new package was available, there for all four samples where acquired. The storage package was already open and stored under the counter. The separation of the cover from the stockpile package was very difficult. The offering system for the covers is located on the counter as visible in Figure 44. The covers are handled by the customers.

Figure 45 Sample location 5, inside the main station

Sample location five where inside the main station of Tampere. Figure 45 shows the storage system behind the counter. The cover are handled by personnel only. The covers are stored next to the sandwich grill and the coffee machine. There was a backup package available which was stored under the counter and already open. All four samples were acquired. Separation seemed to be easy and was done by the personnel.

All samples were taken on the 29.05.2015 by Timo Methler. Every asked shop for the samples were very cooperative and gave the samples willingly. All names are taken out of this thesis for privacy reasons.

The taken samples were analyzed in one of TAMKs laboratories (I0-16). The used clean cards for measuring the amount of proteins are originally designed for a face, 10cm by 10cm. The examined face of the mouth piece of the covers is well under 20% of that space, therefor only one of the five testing areas were used per cover. The color indication scale provided by Orion were numbered and further distinguished, shown in Figure 46.

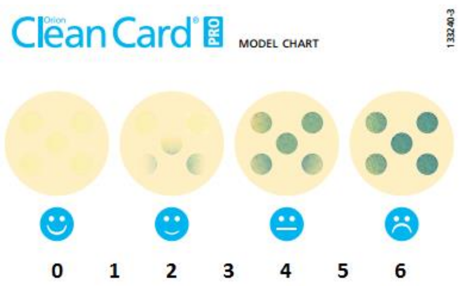


Figure 46 Orion clean card assessment scale

All covers where moistened and wiped as per instruction. The numbers written on the scale in Figure 46 are used in Table 2 to represent the amount of present proteins on the mouthpiece of the respective cover.

Table 2 Sample table and clean card assessment

Sample Location	Sample No.	Position in original stack	Clean Card result
1	1.1	new	1
Next to main bus stop	1.2	top	3
	1.3	middle	2
	1.4	bottom	3
2	2.1	top	2
Next to main bus stop	2.2	middle	2
	2.3	bottom	0
3	3.1	top	1
Central shopping center	3.2	middle	1
	3.3	bottom	1
4	4.1	new	0
Main train station	4.2	top	2
	4.3	middle	0
	4.4	bottom	1
5	5.1	new	2
Main train station	5.2	top	4
	5.3	middle	3
	5.4	bottom	1

9 Conclusion

The development of the coffee cup cover dispenser did not go as it should have. The team that started the development had never heard of structure of development processes and did it more for fun than for professional purpose. Reflected back there should have been structure during the development. Especially documentation of the customer need data acquiring, is vital to the whole development process. The fact that there was no documentation at all made it extremely hard to win new team members or to stay on the original line of thought. But the importance of documentation was not known by the development team and can be related to inexperience. But the team did instinctively the right things during the actual development. The team conducted many interviews to acquire the needed customer needs, it interacted with the product for the intended solution them-self, to experience possible the difficulties. The taken path of concepts however where not optimal. The team was simply too small and too specialized in a single direction. A bigger team with earlier prototyping, for proofs concepts, would have followed different concepts and come to a different solution. The many iterations the attempted solution went through happened because the team did not feel to have found the right solution. These many iterations are recommended and called necessary by the guidelines provided by the literature.

The prototyping was a very big deal of try and error to learn how to use the software and hardware creation tools. The gained knowledge and experience will help to improve quality and speed up future projects. The field of 3D printing is a very new field of study. The progress, in terms of end product quality, using the rather unprofessional personal printer is remarkable. A good example for this progress are Figure 38 and Figure 39. The kind of print is the same but the results of quality differ immensely, although Figure 39 is the more complicated part, it also is the one with the better end quality. Future development will involve earlier and special designed, proof of concept focused and 3D printed prototypes. The responsible professors asked between the second and third system, for a physical proof of concept prototype, but the team did feel to have enough proof with the analytical prototype. This asked for physical prototype should have been done and would be necessary to enable further learning. The team will create the physical proof of concept after the thesis is done. This prototype might enable further development with new personnel and a newly improved system.

The protein testing with the clean card created interesting result which allow first conclusions. Clean Cards are by no means an accurate testing method for this purpose. As explained in the theory other macroelment donators could support the bacterial growth as well. As well as Orion emphasize that Clean Cards might not be able to detect sugars.

Table 3 Clean Card result table

Position in original stack	Location 1	Location 2	Location 3	Location 4	Location 5
New	1	-	-	0	2
Top	3	2	1	2	4
Middle	2	2	1	0	3
Bottom	3	0	1	1	1

On all locations the contamination level reduced from top to bottom, location 1 needs to be excluded from this conclusion, because the storage of mouth piece down, visible in Figure 40. The tested bottom cover from location 1 was directly resting on its mouth piece. The reduction of proteins to the bottom of the stack indicate that the covers protect themselves to a certain degree.

The location with to most present proteins location 5 is the only location at which the covers are handled by the personnel, but the stack is located directly next to the sandwich grill, shown in Figure 45. This sandwich grill is used to heat sold sandwiches and therefor sprays and vaporizes all kinds of proteins into its surroundings. Sorted by proteins present the order is: Location 3, Location 4, Location 2, Location 1 and Location 5. This order is relatable to the distance to the next un-packaged food display/ handling. A side by side comparison, with protein preset in description are on page 38 and page 39 in the appendix. Location 3 with its very low protein present can be called nearly clean, even though the display of covers is on the main counter, close to the money exchange location and customer handled. Which indicates that customer handling is not an issue if watched over by staff. The non-observed customer handling can cause chaos, as visible in Figure 42, there are covers upside down, mixed stacks and, as shown in Figure 41, multiple storage points. Even though Clean Cards are very imprecise the findings are nicely relatable as just explained. These tendencies definitely show the need for further and more precise testing. On the basis of the given Clean Card results the team would suggest a guideline for take away coffee selling shop which include distance to unpacked food and observance by staff or a protection device such as the dispenser in development. The dispenser would prevent the customers from spreading the covers and prevent close up food handling to spread proteins and other nutrients onto the covers.

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11 Appendices

Figure 47 Location 1, mouthpiece down storage high protein presents

Figure 48 Location 2, random storage and customer managed medium protein presents

Figure 49 Location 3, very low protein presents

Figure 50 Location 4, medium protein presents

Figure 51 Location 5, very high protein presents